Attachment G

Erosion and migration of an artificial sand and gravel island - Niakuk III

By: Peter Barnes and Thomas Reiss

INTRODUCTION

Artificial islands and causeways of sand, gravel and mud have been a major proven and, apparently, economical structure used by industry in the exploration and development of petroleum resources in the shallow seas of the Arctic. The' changes these islands undergo in aging will affect their usefulness as structures and their impact on the natural physical and biological environment. Concern has been expressed regarding this impact on faunal habitat, circulation, and ice movement patterns and sediment transport pathways. In this report we address the changes that have occurred at one of these islands in about 4 m of water north of Prudhoe Bay, Alaska (Fig. 1) in an effort to provide insight needed to assess natural versus manmade changes.

Natural islands off the northern coast of Alaska are known to be migrating and changing in shape at a rapid rate. The rates of these changes amount to several meters per year (Barnes et al. , 1977; Reimnitz et al.., 1979; Hopkins and Hartz, 1978; Short, 1979). The offshore islands in this segment of the Beaufort Sea coast are composed primarily of sandy gravels (Hopkins and Hartz, 1978). Niakuk III, an artificial island, is also built of sandy gravels, materials which were mined from a buried river channel on shore. Thus, without erosional protection, this artificial island was expected to change in a manner similar to the natural islands.

A retangular island was built during the winter of 1978-1979. As built, the island measured 95 m by 120 m at the top with base dimensions 150 m by 170 m and used about 100,000 m^3 of fill material. The island extended about 2 m above sea level in water depths of about 4 m.

METHODS

In July 1980 seafloor bathymetry in the vicinity of the island was measured with a 200 kHz fathometer on which depths could be read to within 10 to 15 cm. The observed depths were corrected for tidal difference to the National Ocean Survey's, tide gauge at the West Dock about 11 km to the west. The map was generated from 12 tracklines run in a star-shaped pattern around the island. Navigation on tracklines utilized a precision range-range system and fixes along the trackline are believed to be accurate to within 5 m. The wellhead extended 1.5 m above the island surface as a visual reference point . Bottom samples were obtained using a 10-liter Van Veen grab. Sediment analysis followed standard sedimentologic procedures. For a more complete discussion of field techniques refer to Kempema et al. (1981).

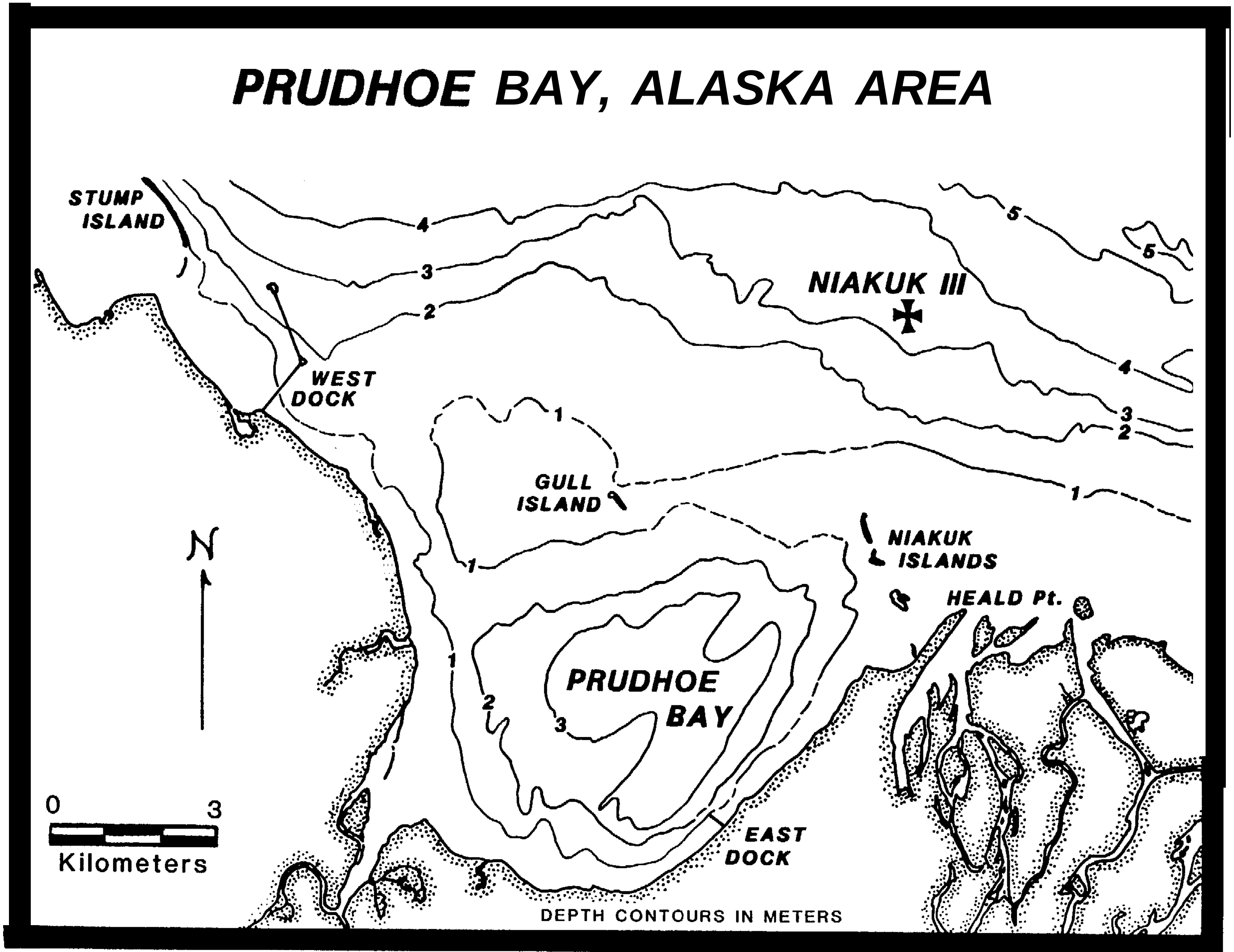

Figure 1. Location map showing the regional bathymetry and location of Niakuk III artificial gravel island.

OBSERVATIONS

Morphology

Niakuk III is located on the broad, shallow northwest flank of the Sagavanirktok River delta front platform in about 4 m of water. The presumed initial shape of the island when open water first allowed wave and current reworking in the spring (June) of 1979 is the above-described rectangle. One year later during July 1980, the morphology of the island had changed significantly both subaerially and subaqueously. The northeastern segment of the island was displaced, eroding the shoreline about 80 m. Recurved subaerial spits were developed to the west and south extending 70 to 80 m beyond the original shores of the island. Only the southwest corner of the island appeared in 1980 as it did when first built one year previously (Fig. 2).

The submerged part of the island shows reworking and migration to the west, the north, and to the south covering an area about double the original base area of the island. The steep slopes on the northeast flank of the island drop to approximately pre-island depths within about 40 m of the island. On the north side of the island a platform-like tongue extends about 100 m to the north at 3 to 4 m depth while to the west and south the subaqueous extensions of the spit slope smoothly to the surrounding sea floor.

Sediments

The sediments of the sea floor in the vicinity of the island are slightly muddy sands (Barnes et al., 1980). No gravels were sampled within several km (Fig. 3). The emplacement of the island and subsequent modification affected the sediment regime in the immediate vicinity. The island was built primarily of gravel, but 5 to 10 percent of the fill was less than 0.25 mm in diameter or finer than medium sand (Northern Technical Services, 1981).

Sampling in 1980 (1 1/2 years since construction] showed that gravels were being left as a lag to the northeast of the island where the island was eroded (Fig. 4). To the southwest and west fine-grained sediments have been deposited. Samples do not extend far enough to the west to determine the limit of these fines. However, it is apparent that gravels are not being carried beyond the spits of the island. The sample taken at the toe of the northwestern spit is a sandy mud. The two samples to the north and east at greater than 75 m from the island are similar to tune regional sediments (Fig. 3), sandy and slightly muddy, indicating little or no gravel or mud deposition in this direction.

Other Observations

Visual observations taken in 1979, 1980, and 1981 also indicate the alteration of the island morphology. Photographs taken in the summer of 1979, the summer after construction of the island, show that the northeast corner had become rounded and that spits had developed on the northwestern and southeastern margins (Fig. 5). By 1980, the year of the detailed survey, the northeast quadrant had retreated. further and the spits had been extended. The

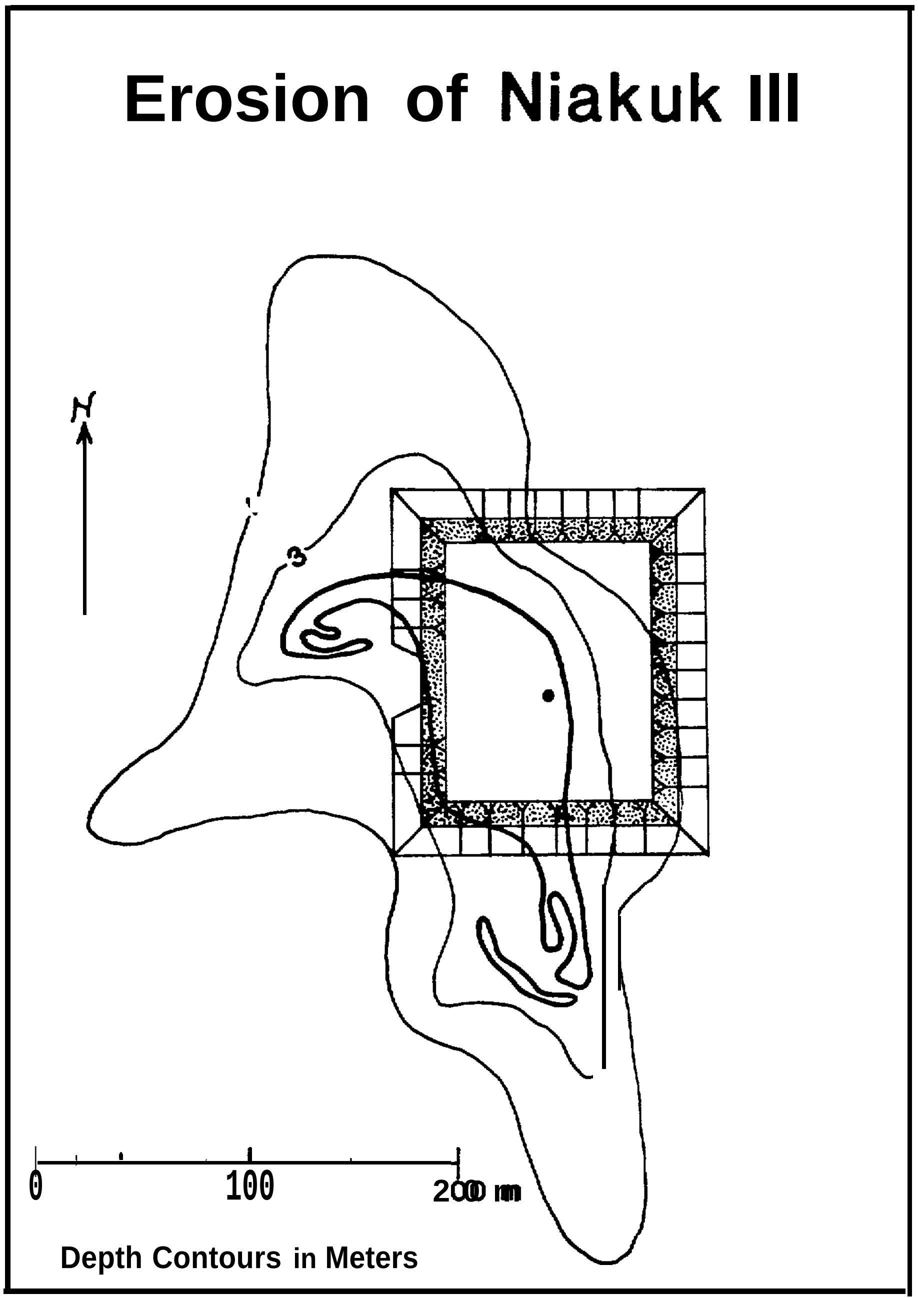

Figure 2. Niakuk III as originally built superimposed on its shape as determined from the 1980 survey data.

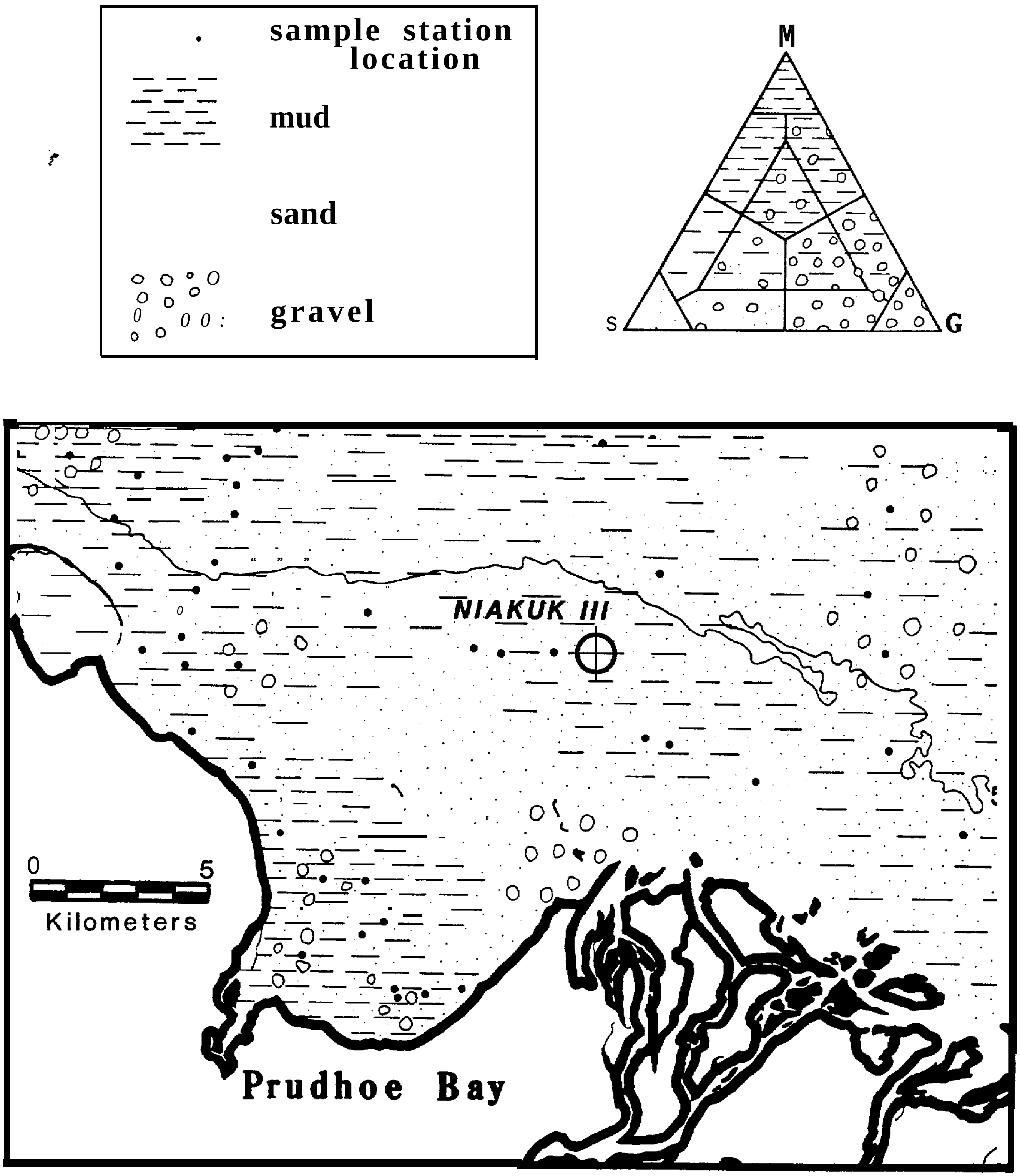

Figure 3. Sediment texture of the sea floor in the vicinity of Niakuk III (after Barnes, et. al., 1980).

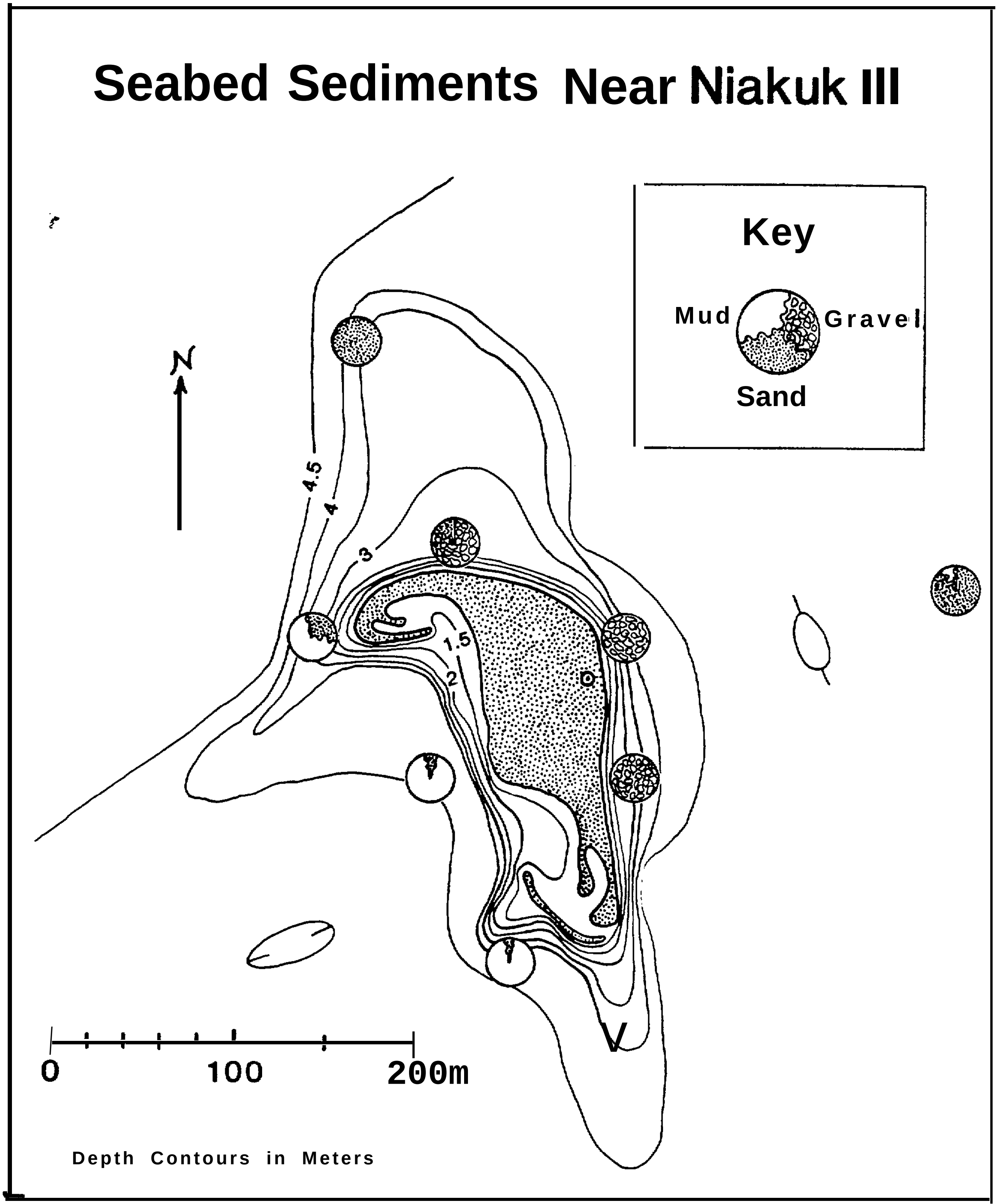

Figure 4. Location and sediment texture of 1980 samples in the immediate vicinity of Niakuk III.

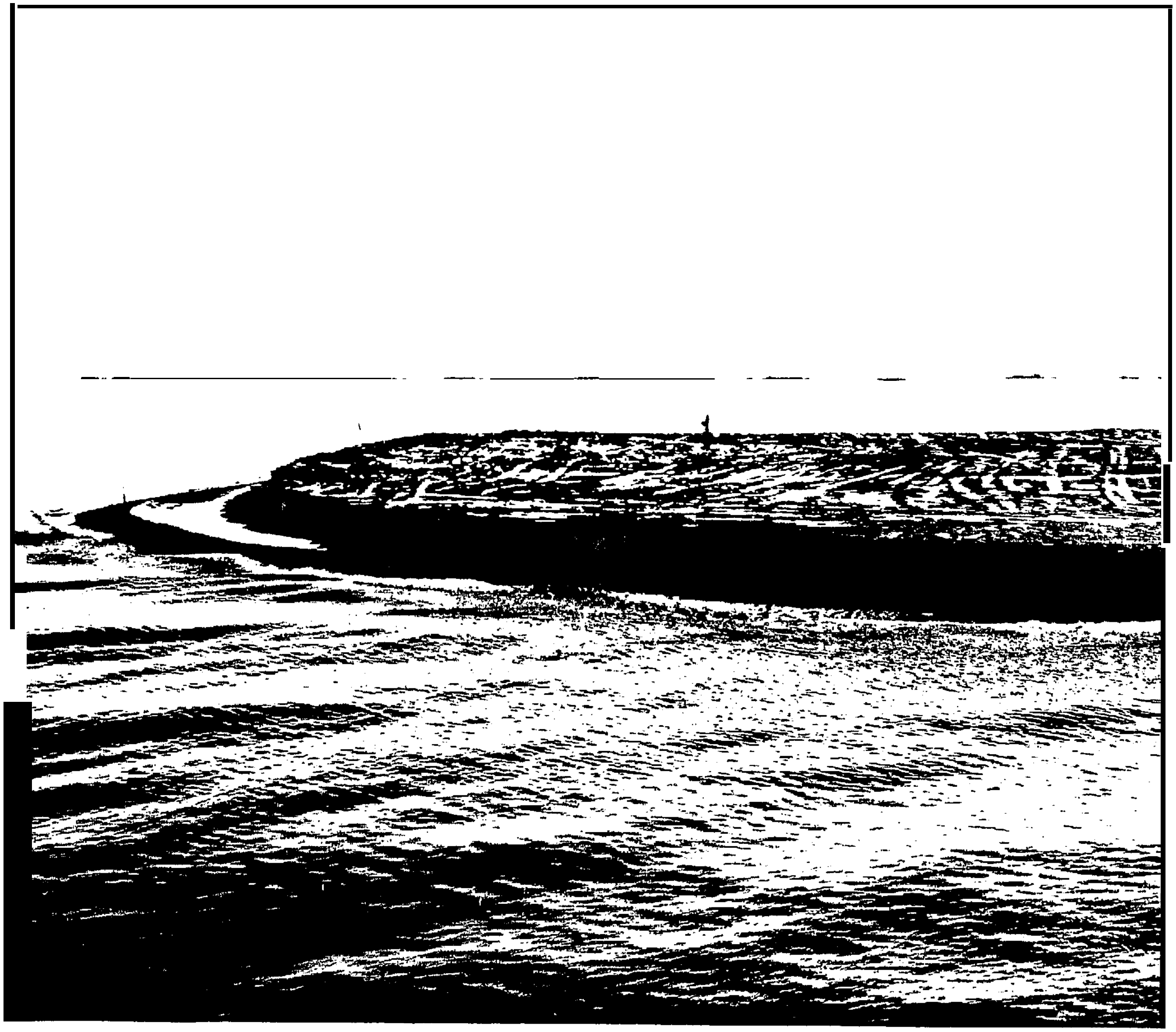

Figure 5. View of the NE corner (left) of Niakuk III taken in September of 1979 (view to the southeast). Note essentially square shape and location-of well head.

wellhead ... from the northeast-facing shore (Fig. 6). By the summer of 1981, the wellhead was about 5 m offshore. The island appeared diminished in size, partly due to the removal of 21,600m^3 of gravel at the end of the summer of 1980 for the construction of other islands (Northern Technical Services, 1981).

DISCUSSION

The predominant factor affecting Niakuk III island has been erosion and redeposition of the northeast quadrant of the island. After being built in the winter of 1978-79, the island was exposed to one open-water season (summer 1979) prior to our early summer survey in 1980. Figures 3 and 5 suggest about a third of the island had been displaced from its original emplacement site during this season. Given that the original volume of the island was abut 100,000 m^3, then at least 30,000 m^3 would have been reworked, transported, and redeposited during the open-water season in 1979. This is a very high rate compared to natural coastal sediment transport to be expected for one year for arctic sand and gravel beaches (Nummedahl, 1979). This high rate is believed 'to be related to the fall storm discussed below or the lack of a substantial permafrost core.

The development of spits on the western and southern corners and the lack of erosion in the southwestern quadrant of the island are a response to the regional and local wind regimes. Supplemental to the dominant regional northeasterlies, a diurnal northeasterly summer sea breeze is developed (Kozo and Brown, 1979). These northeasterlies are responsible for both the erosion of the northeastern quadrant and the development of spits. The generally weaker and less prevalent westerlies and southerlies explain the lack of erosion in the southwestern quadrant but may be responsible for the recurvature of the spits. A similar gravel spit developed off the western tip of the West Dock, primarily during a late September storm in 1979 (Barnes and Ross, 1980).

The unnaturally steep slopes of the artificial island may act to increase the rate of sediment transport and reworking. Wave energy would not be partially dissipated on the gradually sloping seabed as it is at some distance from natural island. Rather, the full force of the waves could be brought right to the island coast, providing increased wave energy to modify the shape of the island and transport sediments.

Another factor that may be related to the rapid eroson of the island is a lack of a well developed permafrost core. The lack of such permafrost would increase the rate of erosion , especially during storms. During storms the presence of a well-developed permafrost would inhibit coastal erosion by acting as a cement, bonding sand and gravel together and making the islands less susceptible to erosion. Storms are suggested, as normally we observe that coastal and beach permafrost is well below the level of normal wave reworking.

Fine-grained sediments released during the construction of the island and during the subsequent reworking of the northeastern quadrant are believed responsible for the fine-grained sediments noted on the sea floor to the

Figure 6. **Photograph** of the NE corner of **Niakuk** III taken In July, **1980.** View **is** from the **east.** Note **spit** to south (left) and the location of the well head near **the** bluff.

s , and (Fig. 3). The lack of gravels in the lee of the ... the spits suggests that neither current nor ice have ... quantities of gravel far from the island. Thus, ... of the island removed for construction pruposes, the ... originally emplaced at Niakuk III has been morphologically altered at ... sported only short distances.

The long-term changes to Niakuk III can only be approximated with the existing observations of an extremely dynamic system. The island will continue to migrate to the southwest as the materials from the original island are used as a sediment source for the elongation of spits. Migration will result in retreat for the northeastern shore of at least 5 m per year based on the retreat of other offshore islands (Reimnitz et al., 1977). The resulting southwesterly migration of the island will probably leave a pavement of lag gravel on the sea floor, remnant from the passage of the island mass.

The ultimate shape of the island is unknown. The island could take the form of one of the small islets common in the chain of sand and gravel islands along the Beaufort coast. These are crescent-shaped features oriented with the long axis northwest-southeast (Nummedahl, 1979). Another form could be a submerged northeast-trending ridge such as Dinkum Sands, (Reimnitz et al., 1980). Whatever the shape, the island will continue to migrate in a westerly direction.

CONCLUSIONS

1. Northeasertly winds and waves significantly altered the original shape of an artifical gravel island in 3 open-water seasons - 1979, 1980, and 1981. The northeast quadrant was eroded back in excess of 80 m and spits were built to the west and south with the eroded material.

2. Coarse-grained materials are remaining within the island mass and as a lag where the island was constructed. The fine-grained sediment from island construction activity and subsequent reworking of island material by waves are blanketing the seabed to the southwest. The migration of lag gravels and siltation have and will continue to affect an area of the seabed much larger than the original emplacement area of the island.

3. Rapid rates of erosion and modification can be expected on similarly built islands and causeways unless measures are taken to protect the northeast quadrant from erosion and longshore drift.

REFERENCES

Barnes, P.W., Reimnitz, E., and Ross, R, 1980, Nearshore surficial sediment textures, Alaska, U.S. Gelogical Survey Open-File Report 80-196, 41 p.

Barnes, P.W., Reimnitz, E., Smith, G., and Melchior, J., 1977, Bathymetric and shoreline changes, northwestern Prudhoe Bay, Alaska, U.S. Gelogical Survey Open-File Report 77-161, 10 p.

Barnes, P.W., and Ross, C.R., 1980, Fall storm, 1979 - a major modifying coastal event in National Oceanic and Atmospheric Administration, Environmental Assessment of the Alaskan Continental Shelf: Principal Investigators Reports, April to December, 1979, v. 2, p. 238-249.

Dygas, J.A., and Burrell, D.C., 1975, Dynamic sedimentologic processes along the Beaufort Sea coast of Alaska, in: Assessment of the Arctic Marine Environment, Hood, D.W. and Burrell, D.C. (eds.), Occassiona Publication no. 4, Institute of Marine Science, University of Alaska, Fairbanks, p. 189-203

Hopkins, D.M., and Hartz, RoW., 1978, Coastal morphology, coastal erosion, and barrier islands of the Beaufort Sea, Alaska, U.S. Gelogical Survey Open-File Report 78-1063, 54 p.

Kempema, E.W., Reimnitz, E., and Barnes, P.W., 1981, Marine geologic studies in the Beaufort Sea, Alaska, 1980; data type, location, records obtained, and their availability: U.S. Gelogical Survey Open-File Report 81-241, 4 p.

Kozo, T.L., and Brown, R.A., 1979, Meteorology of the Alaskan arctic coast, NOAA-OCSEAP Annual Report RU-367, NOAA, Boulder, Colorado, v. 8, p. 1-56.

Northern Technical Services (NORTEC), 1981, Environmental effects of gravel island construction, Endeavor and Resolution Islands, Beaufort Sea, Alaska, unpublished report to SOHIO Alaska Petroleum Company by Northern Technical Services (NORTEC), Anchorage, Alaska, 62 p.

Nummedahl, D., 1979, Coarse-grained sediment dynamics - Beaufort Sea, Alaska, POAC Proceedings, August 13-18, 1979, Norwegian Institute of Technology, p. 845-858.

Reimnitz, E., Barnes, P.W., and Melchoir, J., 1977, Changes in barrier island morphology - 1949-1975, Cross Island, Beaufort Sea, Alaska, U.S. Gelogical Survey Open-File Report 77-477, 14 p.

Reimnitz, E., Kempema, E., Ross, R., and Olson, R., 1979, Additional. observations on geomorphic changes in the arctic coastal environment, NOAA-OCSEAP Annual Report RU 205, NOAA, Boulder, Colorado, p. 1-17.

Reimnitz, E., Ross, C.R., and Barnes, P.B., 1980, Dinkum Sands: U.S. Geological Survey Open-File Report 80-360, 11 p.

Short, A.D., 1979, Barrier island development along the Alaskan-Yukon coastal plains, Geological Society of America, Bulletin 90(2):77-103.